



What can fuel price increases tell us about the air pollution health co-benefits of a carbon price?

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ABSTRACT

Background: Despite their currency, there is little ‘real-world’ evidence for the health co-benefits of policies to reduce carbon dioxide emissions.

Objectives: To explore whether increases in market petrol and diesel price have a discernible impact on ambient air pollution.

Methods: A causal diagram informed the analysis. Linear regression was conducted on weekly air pollutant time-series (PM₁₀, NO_x, PM_{2.5} and CO) for four air quality monitoring stations around New Zealand, and diesel and petrol pricing data, from 2001 to 2013. We explored the possible delayed effects of petrol and diesel price changes over 9 weeks. Flexible cubic splines were used to remove seasonal and long-term trends. Meta-analysis of results from the four stations was undertaken, as were sensitivity analyses.

Results: The unlagged adjusted models for each air quality station and the meta-analyses showed a modest, non-significant reduction in air pollutants (PM₁₀, NO_x, PM_{2.5} and CO) associated with an increase in petrol price. For example, a 1% increase in petrol price was associated with a 0.32% (−1.21 to 0.58) reduction in NO_x. All confidence intervals included null. While the lagged adjusted models showed patterns suggestive of an initial drop in air pollutants after a fuel price rise, followed by a rebound increase over the nine-week period studied, the majority of estimates were non-significant.

Conclusions: The findings are suggestive of a short-term reduction in air pollutants associated with regular petrol or diesel fuel price rises, followed by a rebound increase. Further work could explore the specific pathways between fuel price and air pollution.

1. Introduction

The positive health impacts of policies to reduce carbon dioxide emissions (decarbonise) in the transport sector are the subject of considerable policy and research interest (Watts et al., 2015). Studies modelling potential policy scenarios consistently suggest that reducing reliance on fossil fuels for transport could have substantial positive health impacts. For example, a shift from private motor vehicles to active (e.g. cycling and walking) and public transport modes as a result of policies to reduce carbon dioxide emissions could lead to health co-benefits, including reduced injuries from road traffic crashes, and improved disease outcomes through reduced air pollution and increased population physical activity (Creutzig et al., 2012; Macmillan et al., 2014; Rojas-Rueda et al., 2012;

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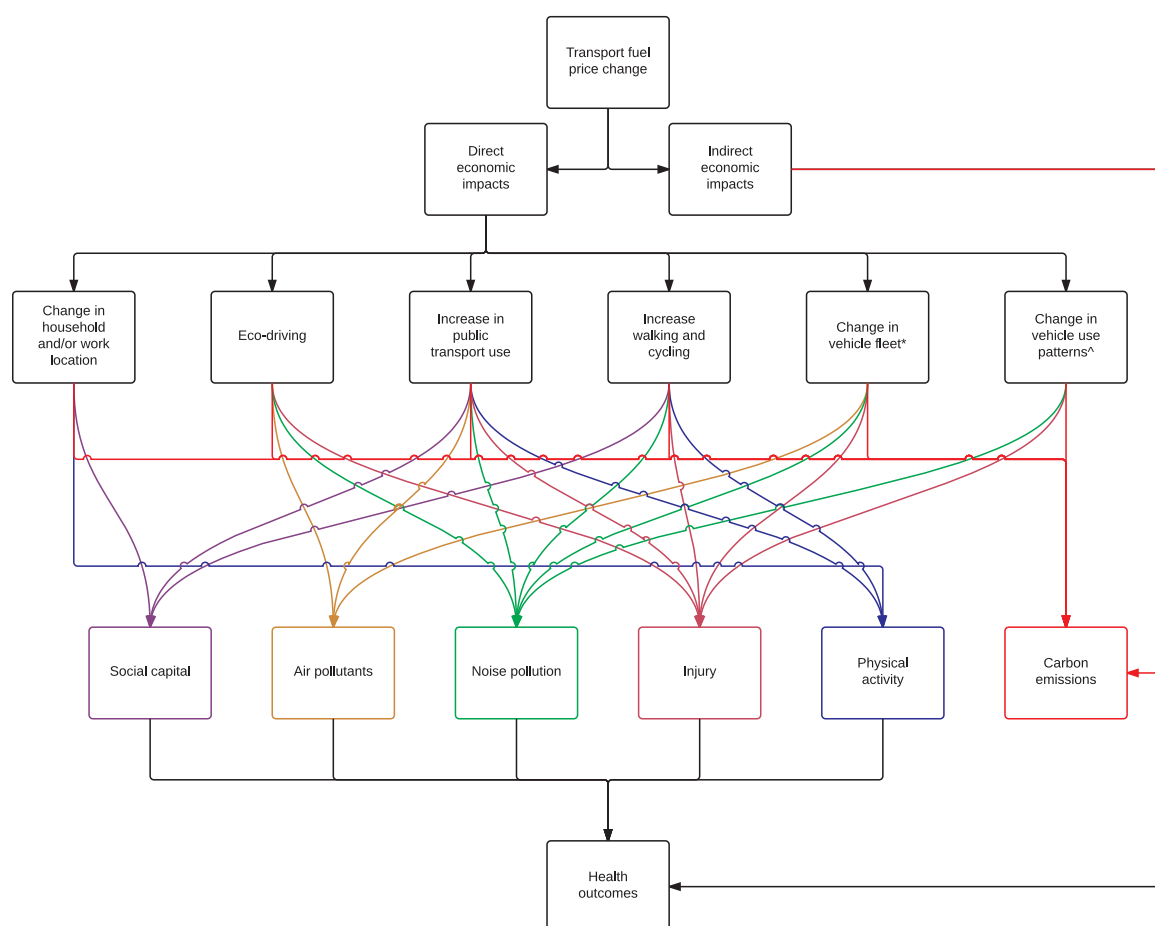


Fig. 1. Theoretical pathways between transport fuel price and health and carbon impacts. Figure footnote *For example, trip reductions, trip chaining, carpooling *For example, fewer car purchases, retiring of older vehicles, conversion to more efficient vehicles such as hybrids, diesels, 2-wheelers, ethanol/biofuel vehicles.

Woodcock et al., 2009). Due to these positive health impacts, decarbonisation policies are thought to be highly cost-effective and sometimes cost-saving (Jarrett et al., 2012; Jensen et al., 2013; Macmillan et al., 2014).

There are two broad issues with using scenario modelling studies as a source of evidence for policy development. Firstly, there are considerable methodological limitations in some studies. For example, limited approaches to deal with stochastic and parametric uncertainty in the models (Remais et al., 2014). Secondly, scenario modelling studies are unable to deal with the reality of policy-making, where policies may not be implemented, be poorly implemented, fail to deliver the expected outcomes and/or have unanticipated effects.

Thus, evidence from modelling needs to be supported by real-world research, including trials or evaluations of decarbonisation policies and natural experiment evaluations. Currently empirical evidence in this area is limited and/or of poor quality (Shaw et al., 2014). Innovative approaches are needed to provide empirical evidence for policy-making and analysis.

As part of decarbonisation policy packages, multiple international institutions now recommend an effective price on carbon emissions (Aldy, 2015). Pricing policies are generally emissions trading schemes and/or taxes. Approximately 12% of the global carbon emitted is now part of a pricing scheme (World Bank, 2015). While use of carbon pricing in the transport sector has varied, it has had a large impact in British Columbia, Canada with a 19% per capita reduction in fuel use in the four years after implementation in 2008 (Ecofys and World Bank, 2014).

After reviewing the literature (Shaw, 2016), we created a diagram of the theoretical pathways between land transport fuel price and health and carbon emission outcomes (see Fig. 1). Potential pathways to health outcomes include changing travel modes and patterns of vehicle use, and relocating employment and housing.

To our knowledge, there has been no ‘real-world’ assessment of the health impacts of existing carbon pricing tools. It is extremely challenging to evaluate these health impacts: best-practice epidemiological methods such as randomised controlled trials are difficult, if not impossible, to apply in this setting. Other robust epidemiological methods may also be unsuitable to evaluate health impacts. A carbon tax in British Columbia, Canada was gradually implemented over a number of years (Rivers and Schaufele, 2014), for example, making interrupted time-series analysis difficult (Kontopantelis et al., 2015). Non-methodological issues can also make evaluation challenging: the poor design of the New Zealand emission trading scheme, for instance, resulted in an ineffective carbon

price with no discernible impact on fuel price (Ecofys and World Bank, 2014; Ministry of Transport, 2014; Wright, 2015).

We examined whether the natural experiment of changes in petrol and diesel prices in New Zealand between 2001 and 2013 were associated with changes in observed concentrations of transport-related air pollutants. We theorised that alterations in air pollution in response to price changes in petrol and diesel price would be similar to price responses from an effective carbon pricing policy on transport fuel.

We investigated whether fuel prices were associated with short-term transport-related urban air pollution in New Zealand as well as whether there were differences in response to price by type of fuel. We also examined the temporal dimension of any response to changes in fuel price.

2. Methods

2.1. Theory

We used the theoretical framework of pathways between fuel price and health (Fig. 1) to inform a causal diagram for the analysis (Appendix A). The causal diagram guided the choice of covariates (Glymour, 2006; Glymour and Greenland, 2008) relevant on the weekly timescale of the analysis (Bhaskaran et al., 2013). Public holidays were included in the model as potential confounders (in causal diagram terminology, to block backdoor pathways between exposure and outcome via car use and public transport). Weather variables were not included in the main analysis as the causal diagram indicated they would not act as confounders (in causal diagram terminology, the pathways were already blocked by public transport and car use acting as colliders). Further discussion of causal diagram theory and the specific rationale of this causal diagram can be found elsewhere (Glymour and Greenland, 2008; Hernan et al., 2002; Shaw, 2016). Given the inclusion of weather-related variables in analyses exploring determinants of air quality, additional sensitivity analyses were performed with relevant variables, such as temperature, humidity, wind speed and wind direction.

2.2. Data

2.2.1. Exposure

Weekly petrol and diesel prices in New Zealand 2001–2013 (see Fig. 2). These data were collected by oil consultancy firm Hale and Twomey. Their staff assess the headline retail price for the larger metropolitan centres, excluding any discounting, and adjusts the price in their data series when the majority of market participants have changed price. Petrol and diesel prices in New Zealand are determined by a combination of international oil price, international exchange rates and national-level excise tax. Retail petrol and diesel prices are similar across main metropolitan centres (Twomey and West, 2008). Prices were Consumer Price Index adjusted using information from Statistics New Zealand.

2.2.2. Outcome

Air pollution outcomes were assessed using data from four air quality monitoring stations around New Zealand (data from these stations were provided by Auckland Council, Ministry for the Environment and Greater Wellington Regional Council). These were selected using the following criteria: firstly, location near busy roads with traffic as the predominant source of pollution; secondly, air pollutants monitored included nitrogen oxides (NO_x), particulates (PM_{10} , $\text{PM}_{2.5}$) and carbon monoxide (CO); and, thirdly, having more than 3 years of data available. Data from one Wellington station (Victoria St) and three Auckland stations (Khyber Pass Rd, Penrose, Takapuna) met these criteria. Pollutant measurements were converted to $\mu\text{g}/\text{m}^3$ where required and mean weekly air pollutant levels were created to match the weekly petrol and diesel price data. If less than 80% of air pollutant values were present in

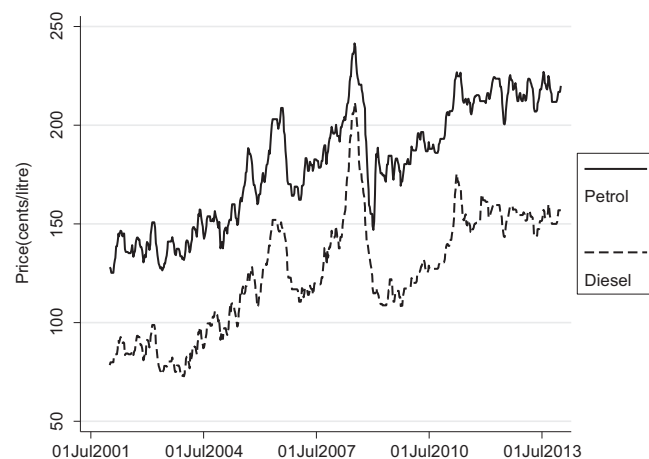


Fig. 2. Weekly retail petrol and diesel prices New Zealand 2001–2013. Figure footnote: Prices CPI adjusted to 2013.

a week, the weekly value was set to missing.

2.2.3. Covariates

historical public holiday dates in New Zealand were obtained from the Department of Internal Affairs and a binary variable created.

No exposure or covariate data were missing. The amount of missing outcome data varied by pollutant and monitoring station, and ranged from 1% to 7%. Because the investigation of missing data suggested it was mostly missing completely at random, due to equipment malfunctions or maintenance, complete case series analysis was undertaken.

2.3. Analysis

Time-series regression modelling was undertaken in the following steps: data de-trending, regression modelling, exploration of lagged exposure relationships, sensitivity analyses, model checking, meta-analysis. Analyses were conducted separately for the four locations, prior to meta-analysis.

2.3.1. De-trending data

Removal of the seasonal and long-term trends is required in order to determine whether short-term changes in petrol and diesel prices are associated with short-term changes in air pollutants (Bhaskaran et al., 2013). After testing a number of different de-trending methods, seasonal and long-term trends were removed from the exposure and outcome data using flexible cubic splines (frencurvnc command in Stata). Knots were set to seven per year, unless inspection of regression residuals using correlograms suggested that fewer knots were adequate to remove trends from the data (Bhaskaran et al., 2013). An example of the NO_x data from one monitoring station before and after the de-trending process is shown in Appendix B. Further details of the de-trending and sensitivity analyses around de-trending are available elsewhere (Shaw, 2016).

2.3.2. Regression modelling

A linear model was fitted using the regression residuals from the de-trending process as the exposure, and the model was adjusted for the presence of a public holiday during a given week. Exposure and outcome were both converted to natural logs prior to modelling which allowed the result to be interpreted as a percentage change (similar to interpreting an economic elasticity).

2.3.3. Exploration of lagged relationships

Petrol or diesel price was lagged from 0 to 8 weeks. Only limited exploration was possible due to model instability in unconstrained distributed lag modelling and the lack of a theoretical basis to constrain the models (Bhaskaran et al., 2013). There was no published precedent for choice of a time frame around the exploration of delayed effects of the exposure (fuel price). We explored out to 9 weeks as a time-frame that might plausibly make short-term changes visible, if they existed, but not so long that long-term trends (such as vehicle fleet changes) might confound any association.

2.3.4. Sensitivity analyses

We tested the impact of reducing the number of knots in the splines, and including meteorological variables provided by the National Institute of Water and Atmospheric Research (which are commonly included in air pollution analyses) as covariates in the model.

Table 1

Estimate and 95% confidence intervals of petrol and diesel price and transport-related air pollutants (unlagged).

Fuel type	Station	NO _x (95% CI)	CO (95% CI)	PM ₁₀ (95% CI)	PM _{2.5} (95% CI)
Petrol	Khyber Pass Road	-0.71 (-3.04 to 1.61)	-1.81 (-3.68 to 0.06)	-1.00 (-1.95 to -0.05)	N/A
	Penrose -	0.25 (-2.30 to 1.79)	N/A	-0.25 (-1.04 to 0.53)	-0.28 (-1.36 to 0.80)
	Takapuna	-1.64 (-3.33 to 0.05)	-0.87 (-2.55 to 0.81)	-0.40 (-1.23 to 0.43)	-0.78 (-2.37 to 0.81)
	Victoria St	0.80 (-0.66 to 2.26)	0.57 (-0.83 to 1.98)	0.03 (-0.68 to 0.75)	N/A
	Meta-analysis	-0.32 (-1.21 to 0.58)	-0.60 (-1.99 to 0.80)	-0.33 (-0.74 to 0.07)	-0.46 (-1.32 to 0.46)
Diesel	Khyber Pass Road	-1.06 (-2.62 to 0.50)	-1.18 (-2.50 to 0.14)	-1.55 (-2.72 to -0.38)	N/A
	Penrose	0.12 (-1.41 to 1.64)	N/A	-0.41 (-1.08 to 0.27)	-0.13 (-1.20 to 0.94)
	Takapuna	-0.68 (-1.91 to 0.54)	-0.77 (-1.98 to 0.44)	-0.46 (-1.19 to 0.27)	-0.64 (-1.96 to 0.67)
	Victoria St	0.69 (-0.61 to 2.00)	0.06 (-1.45 to 1.56)	-0.08 (-0.84 to 0.67)	N/A
	Meta-analysis	-0.21 (-0.90 to 0.48)	-0.70 (-1.46 to 0.07)	-0.49 (-0.97 to 0.02)	-0.33 (-1.16 to 0.50)

Table footnote: Linear regression models adjusted for seasonal and long-term trends and public holidays. Analysis dates: NO_x Khyber Pass: 31 December 2001 to 11 January 2009, Penrose: 31 December 2001 to 31 December 2013, Takapuna: 24 March 2003 to 31 December 2013, Victoria St: 5 March 2005 to 31 December 2013, CO Khyber Pass: 31 December 2001 to 5 January 2009, Takapuna: 31 December 2001 to 31 December 2013 Victoria St: 1 Jan 2008 to 31 December 2013, PM₁₀ Khyber Pass: 3 April 2006 to 27 December 2010, Penrose: 26 May 2003 to 31 December 2013, Takapuna: 2 February 2004 to 31 December 2013, Victoria St: 5 March 2005 to 31 December 2013, PM_{2.5} Penrose: 14 August 2006 to 31 December 2013, Takapuna: 18 June 2007 to 31 December 2013. Meta-analyses: Fixed effects model: NO_x, Random effects model: CO, PM₁₀, PM_{2.5}.

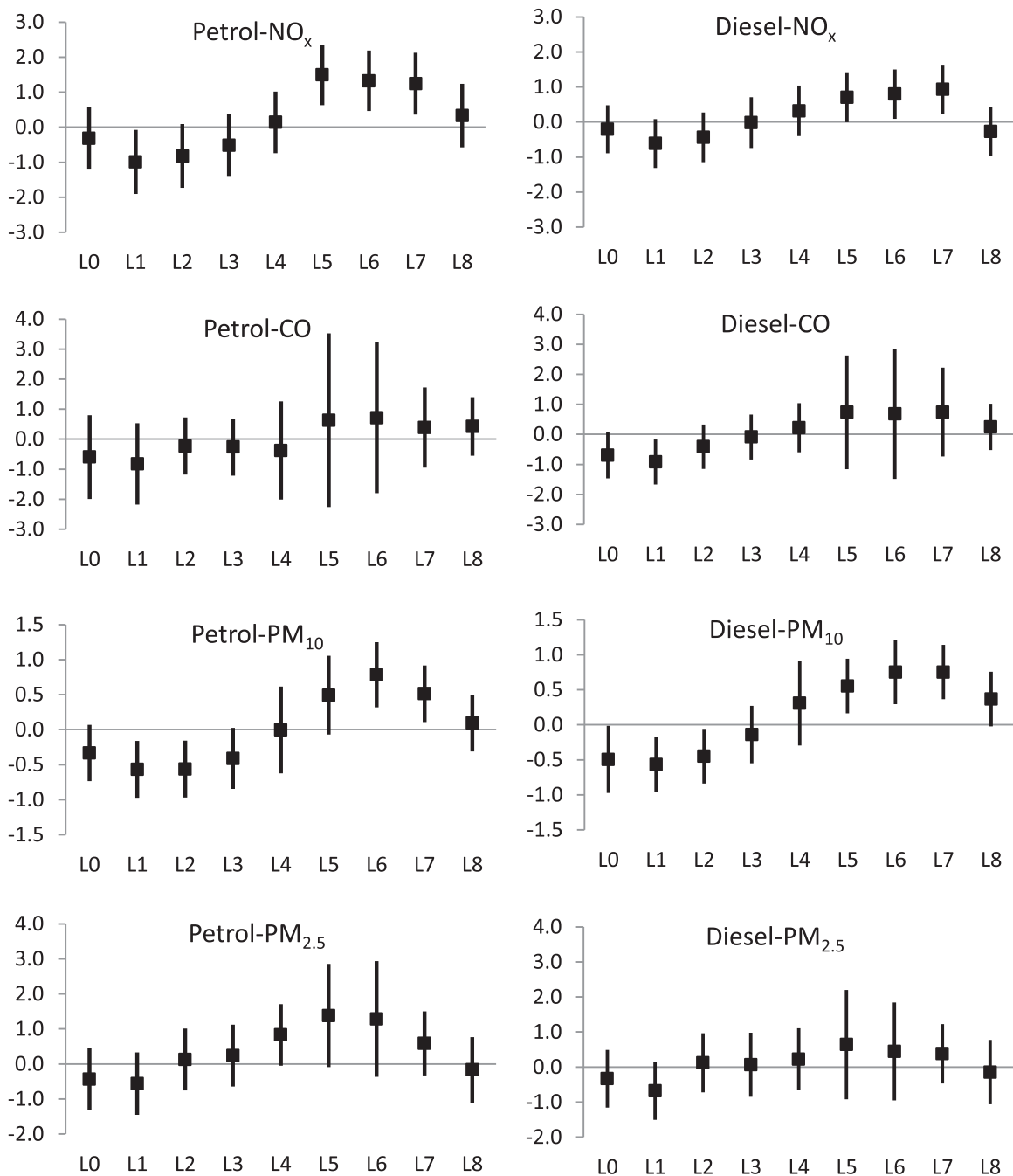


Fig. 3. Meta-analysis of lagged relationships between petrol and diesel prices and air pollutants. Figure footnote: Meta-analyses: Fixed effects model: NO_x, Random effects model: CO, PM₁₀, PM_{2.5}.

2.3.5. Meta-analysis

For each weekly lagged combination of exposure and outcome, we undertook meta-analysis of the results for all four air quality stations using a regression model. For example, for the petrol price-NO_x relationship, we combined the results from the four monitoring station for L0, L1, L2, L3 etc. We used a fixed effects or random effects approach depending on whether the lagged exposure models had an I^2 less than or greater than 50% respectively.

All analyses were conducted using Stata version 12.1 (StataCorp. 2011. Stata Statistical Software: Release 12. College Station, TX: StataCorp LP).

3. Results

Table 1 shows the results of the adjusted linear regression models examining the association between unlagged petrol and diesel price and transport-related air pollutant outcomes. Results are shown for each air pollution monitoring station and from the meta-analysis. The majority of estimates showed a non-significant negative association between unlagged price and pollutant outcomes. For example, a 1% rise in petrol price was associated with a 0.25% (95%CI: –2.30 to 1.79) increase to –1.64% (95%CI: –3.33 to 0.05) reduction in NO_x levels in the three Auckland-based air quality monitoring stations. For PM_{2.5}, a 1% rise in diesel price was associated with a –0.13% (95%CI: –1.20 to 0.94) to –0.64% (95%CI: –1.96 to 0.67) decrease in PM_{2.5} in Penrose and Takapuna. The meta-analyses also showed a reduction in pollutants associated with a rise in price. For example, carbon monoxide decreased –0.60% (95%CI: –1.99 to 0.80) for a 1% rise in petrol price and PM₁₀ by –0.49% (95%CI: –0.97 to 0.02) for a 1% rise in diesel price. All confidence intervals of the estimates included the null, including the pooled estimates from the meta-analyses, in other words the estimated association of petrol or diesel price on ambient emission concentrations is not statistically significant.

Fig. 3 presents the meta-analysis (all four air quality stations combined) of each lagged regression, stratified by fuel type and air pollutant outcome. Each figure shows the unlagged model (L0), followed by the models with prices lagged by one week (L1) to eight weeks (L8) prior to the pollutant measurement. Air pollution fell in the first weeks after a price rise, then increased in the later time period, and returned to near the null by the end. Again, the majority of the estimates have confidence intervals that include the null.

Sensitivity analyses examined the impact of including weather variables and altering the knots on splines. These did not alter the direction or statistical significance of the relationships substantially. Further details and results of the sensitivity analyses are available elsewhere (Shaw, 2016).

4. Discussion

The analysis shows an inconclusive association between increasing diesel or petrol prices and short-term changes in transport-related air pollutants. Reductions in pollutants of between 0.5 to 1% were seen in the initial two to three weeks associated with a 1% rise in fuel price. There was then a rebound increase in pollutants and subsequent return to around the null over the nine-week period of analysis. The majority of individual estimates were not statistically significant, even when pooling results across the four air quality monitoring stations. The pattern of these associations was consistent across all four transport-related air pollutants analysed, as was the lack of statistical significance.

Few studies have explored the direct association between fuel price changes and air pollution. One analysis from Brisbane from 2010 to 2013 found an association between increase in diesel price and reduction in NO_x (30%) and CO (70%), but found no association for particulates. Furthermore no association was found between petrol price and any transport-related air pollutants (Barnett and Knibbs, 2014). An unpublished study from Atlanta, Georgia showed similar results to this one (Boehmer et al., 2011). Both studies only examined a single lagged exposure-outcome relationship of about 2 weeks and differed in methodology and context for the current analysis (see Appendix C for details). Nevertheless, the results all suggest a small short-term association between fuel price increases and a reduction in traffic-related air pollutants.

4.1. Strengths and weaknesses of analysis

The strengths of this analysis include the long study period that captured large changes in petrol price, the use of multiple air quality monitoring stations, the inclusion of a wide range of air pollutant outcomes and the exploration of lagged relationships over 9 weeks. In addition, misclassification of the exposure and outcome is not particularly significant in this analysis. It is difficult to imagine a plausible scenario where fuel price measurement error and air pollutant measurement error were related, given they are recorded independently and, in the case of air pollutant measurement, largely without human intervention.

Our analysis is underpinned by a strong theoretical base, through exploration of the specific pathways between fuel price and health and the use of a causal diagram to inform the model. Sources of possible residual confounding are twofold. Firstly, the causal diagram might be wrong, leading to omission of important confounders, although we believe this is unlikely, as the causal diagram was informed by research of literature and use of the rules that govern causal diagrams (Glymour, 2006; Glymour and Greenland, 2008) to determine the final model specifications. Secondly, the effect estimates reported in Fig. 3 are each from individual models, and it is likely that the exposure-outcome association in one lagged model is confounded by the exposure-outcome association in other lagged models (Bhaskaran et al., 2013). While this problem is usually managed by distributed lag modelling (Bhaskaran et al., 2013), the unconstrained distributed lag modelling in this analysis resulted in imprecise estimates (Schwartz et al., 1996), and there was no theoretical basis for applying constraints (Bhaskaran et al., 2013) given the absence of previous research. This is an area for further work, including exploring whether novel approaches such as distributed lag non-linear models would be useful (Gasparrini et al., 2010).

The analyses may be underpowered to detect statistically significant findings. Despite multiple attempts to increase the study size by attempting to obtain daily petrol and diesel price data from fuel companies, extend the time-series of weekly data and maximise the number of air quality monitoring stations analysed, it was not possible to increase study power. Similar to other time-series

analyses, there are also issues around the choice of method to remove the seasonal and long-term trends from the data, and deciding on the optimal amount of trend to remove (Bhaskaran et al., 2013; Schwartz et al., 1996). Sensitivity analysis of the number of knots in the splines did not substantially alter the results, however.

4.2. Policy and practice implications

There are a number of possible explanations as to why we would expect to see a reduction in air pollutants in association with fuel price increases (Fig. 1), including reduced trips, increased use of public transport, and eco-driving (the practice of driving in such a way as to minimise fuel consumption and vehicle wear and tear). While the existence of these pathways is supported by literature (Shaw, 2016), we were not able to examine in this work whether any (or all) of these pathways were in action. Testing specific pathways might be a useful approach to strengthen any future work in this area (Greenbaum, 2017).

The findings suggest that there is a rebound effect in the short-term with air quality levels worsening several weeks after a fuel price increase. From an individual behavioural perspective, there are plausible explanations for a rebound, such as journeys that have been deferred in the first few weeks after a price rise needing to be taken and immediate eco-driving awareness fading. In a car-dominated society, it is probably hard to maintain enduring changes, without other supportive policy such as public transport availability.

The concept of a rebound effect is familiar in economics (Druckman et al., 2011; Sorrell et al., 2009). The econometric literature indicates that consumer response to fuel price changes is a dynamic process with distinct short- and long-run responses (Goodwin et al., 2004). Some literature suggests that response to price changes, such as reduced fuel consumption or distance travelled, can be almost instantaneous (Bomberg and Kockelman, 2011; Cozad and LaRiviere, 2013), while others have shown rebound occurring within a short timeframe (Puller and Greening, 1999). While the patterns over the nine-week period examined suggest that there would be little sustained change in either of these outcomes, the short-term response suggests that there is at least potential for change.

This analysis could not explore the important question of a long-term relationship between fuel price and air pollution. Any long-term impact of fuel price rises on air pollution would be mediated through some of the same pathways theorised for the short-term relationship, but also through others, such as increased vehicle efficiency or shifting land-use patterns (Klier and Linn, 2010; Ortuno-Padilla and Fernandez-Aracil, 2013). While there may be feedbacks between different pathways and further rebound effects (Frondel and Vance, 2009), exploring this association would require further research.

It is unclear whether consumer responses to market-led fuel price changes are a valid representation of the impacts of a carbon price. Fuel prices are extremely dynamic. In the price series used in this analysis, there was a change in fuel price on average every 10 days. Depending on the design of a carbon price it could be either akin to the excise tax, which may change annually or less frequently, or involve emissions trading, in which prices might change more often. A carbon price may also be a part of a wider carbon emission reduction strategy with accompanying policies and publicity. These features may make consumer responses to a carbon price differ compared to market-led changes.

Emerging evidence suggests that fuel taxes may result in higher consumer responses when compared to market-led price changes. Two analyses have shown that compared to market-led price changes, tax rises on fuel have seven to eight times greater effects on fuel demand (Rivers and Schaufele, 2015), vehicle efficiency and miles travelled (Li et al., 2012). One paper concluded that 85% of the decrease in carbon emissions in the four years after the British Columbia carbon tax was implemented was due to the additional response to a tax (Rivers and Schaufele, 2015). These findings may not be relevant to emissions trading approaches, which involve more frequent changes to price.

Finally, there are multiple health risk factors and/or outcomes that could be affected by transport fuel pricing mechanisms. While we elected to look at air pollution in this analysis, other areas such as traffic injury, drink driving or physical activity outcomes could also be fruitful research areas (Chi et al., 2013; Chi et al., 2011; Hou et al., 2011). In addition, it remains likely that other transport decarbonisation policies, such as policies that directly promote mode shift to active transport, would result in improvements in air pollution.

5. Conclusions

This analysis is suggestive of an association between increasing petrol and diesel price (a proxy for a carbon tax) and a short-term change in transport-related air pollutants. The findings are consistent with other analyses and theoretical understanding of consumer responses to fuel price rises. The need to provide real-world evidence of the health impacts of decarbonisation policies is imperative. While this work is not able to provide definitive conclusions about the impact of a price on air pollution, we regard it as a starting point to open up further discussion and research in this important area.

Acknowledgments

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Role of funding source

The study sponsor had no role in the study design, collection, analysis, or interpretation of data, in the writing of the report, or in the decision to submit the paper for publication.

Ethics

No ethical approval for the analysis was required as it used routinely collected ecological-level data.

Additional information

None.

Appendix A

Causal diagram of the short-term relationship between fuel price and transport-related air pollution. See Fig. A1.

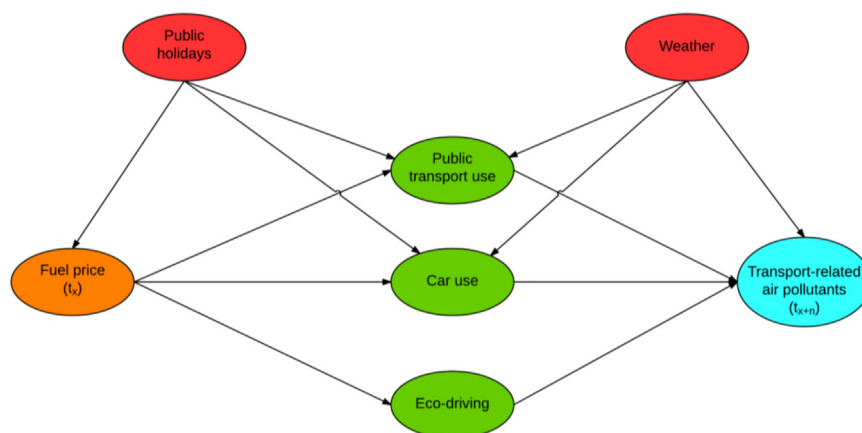


Figure colour key: **Exposure**, **outcome**, **unmeasured causal pathway variables**, **covariates** Note: the unmeasured causal pathway variables only include variables that directly impact on air pollution. For example, cycling and walking are not included because in and of themselves they do not change air pollution, only by reducing car do they impact air pollution.

Fig. A1.

Appendix B

See Fig. B1.

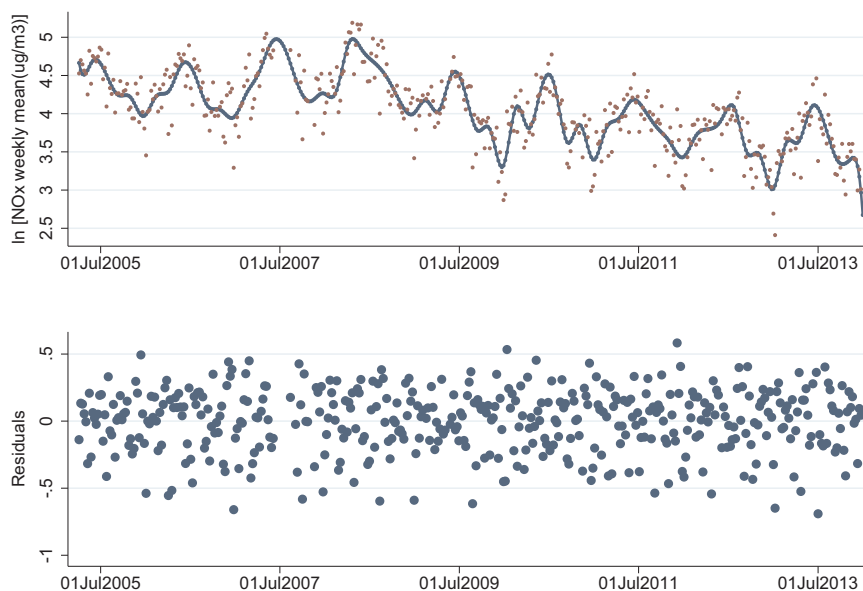


Fig. B1.

Appendix C

Time period Place	Barnett and Knibbs 2010–2013 (3 years) Brisbane, Australia	Boehmer et al. 2006–2008 (2.5 years) Atlanta, Georgia, USA	This analysis 2001–2013 (12 years) Auckland and Wellington, NZ
Population size	2 million	4 million	Auckland 1.5 million, Wellington 0.5 million
Number of air quality stations	2 (unclear what specific pollutants were monitored at each station)	1 each for CO and NO _x (not the same location), 3 for PM _{2.5} (1 was co-located with NO _x)	4
Location of air quality monitoring station	Roadside near city centre	Roadside	Roadside
Traffic conditions at monitoring site	Major roads and freeways carrying 50 000 to 130 000 cars per day	Not stated	Sited on or near roads carrying between 5000 to 120000 cars per day
Exposure	Petrol and diesel prices	Petrol price	Petrol and diesel prices
Outcome air pollutants	PM ₁₀ , PM _{2.5} , NO _x , CO	PM _{2.5} , NO _x , CO	PM ₁₀ , PM _{2.5} , NO _x , NO ₂ , CO
Time-series data intervals	Daily	Daily	Weekly
Model type	Linear regression	Generalised estimating equations (a semi- parametric regression model)	Linear regression
Confounders adjusted for	None stated	Temperature, unemployment, weekday, holiday, humidity	Public holiday during the week, weather as a sensitivity analysis
Seasonal and temporal trend control	Splines	None stated	Splines
Lag period	16 days	11 days	Unlagged and lagged exposures out to 8 weeks

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